U.S. DEPARTMENT OF ENERGY
SMARTMOBILITY
Systems and Modeling for Accelerated Research in Transportation

CONNECTED/AUTOMATED VEHICLES & INTELLIGENT TRANSPORTATION SYSTEMS

June 20, 2023

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Argonne NATIONAL LABORATORY · BERKELEY LAB · INL Idaho National Laboratory · NREL · OAK RIDGE National Laboratory · Pacific Northwest NATIONAL LABORATORY

TODAY'S SPEAKERS

JOSHUA AULD

Group Manager,
Transportation Systems & Mobility

jauld@anl.gov

Argonne National Laboratory

NAWAF NAZIR

Research Scientist,
Energy & Environment Directorate

nawaf.nazir@pnnl.gov

Pacific Northwest National Laboratory

PREVIOUS & UPCOMING WEBINARS

FEBRUARY
OVERVIEW, KEY METRICS AND INSIGHTS SNEAK PEEK

MARCH
MULTIMODAL TRAVEL
Transit & Ridehail

APRIL
MULTIMODAL TRAVEL
Micromobility
Drones

MAY
CONNECTED & AUTOMATED VEHICLES (CAVs)
Vehicle and powertrain control
Traffic signal control

TODAY

JUNE
CAVs and Intelligent Transportation Systems
Transportation system impact, induced VMT, parking, curb management, land use, policies

JULY
FREIGHT
Last mile delivery

AUGUST
ELECTRIFICATION
EV charger deployment
Grid impact

2023

Webinar Materials

IMPACT OF CONNECTIVITY, AUTOMATION AND INTELLIGENT TRANSPORTATION SYSTEMS

- How will connectivity and automation impact system efficiency?
- How do these technologies interact with vehicle efficiency?
- Does connectivity enable better traffic control?
- How do these technologies impact key metrics?

- What opportunities exist for demand management due to new technologies and behaviors?
- How do changing demand patterns interact with new technologies?

- Are there better ways to manage limited curb space in cities?
- How can variable message signs improve system efficiency?

LARGE-SCALE AND FOCUSED STUDIES ON CONNECTIVITY, AUTOMATION AND DEMAND MANAGEMENT STRATEGIES

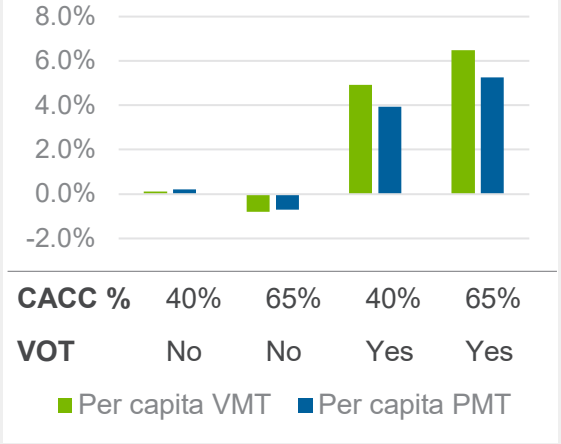
- **Multiple in-depth studies run for different cities focusing on:**
  - Road pricing
  - Automated-driving
  - Connectivity
  - Adaptive Signals
  - Teleworking
- **Explored different combinations of technologies/policies**

MOBILITY IMPROVES WITH COOPERATIVE ADAPTIVE CRUISE CONTROL, BUT REVERSED WHEN VALUE OF TIME (VOT) CONSIDERED

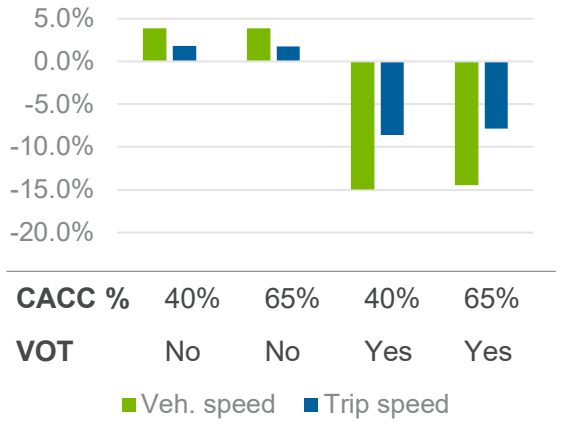
- **Modest improvement in speeds (4%) without VOT induced travel**
- **Including VOT impact increases travel miles from 4.9% to 6.5% with 15% reduction in speed**
- **Improved capacity alleviates some of this impact (same travel for high and very high)**

- **Important to consider the behavioral impacts of transportation technologies**

% Δ in per capita vehicle (VMT) and person miles traveled (PMT)



% Δ in average vehicle and trip speed



1. Assumed VOT reduction of 10% for non-mandatory and 55% for mandatory trips based on preliminary survey data for highway travel

Chicago

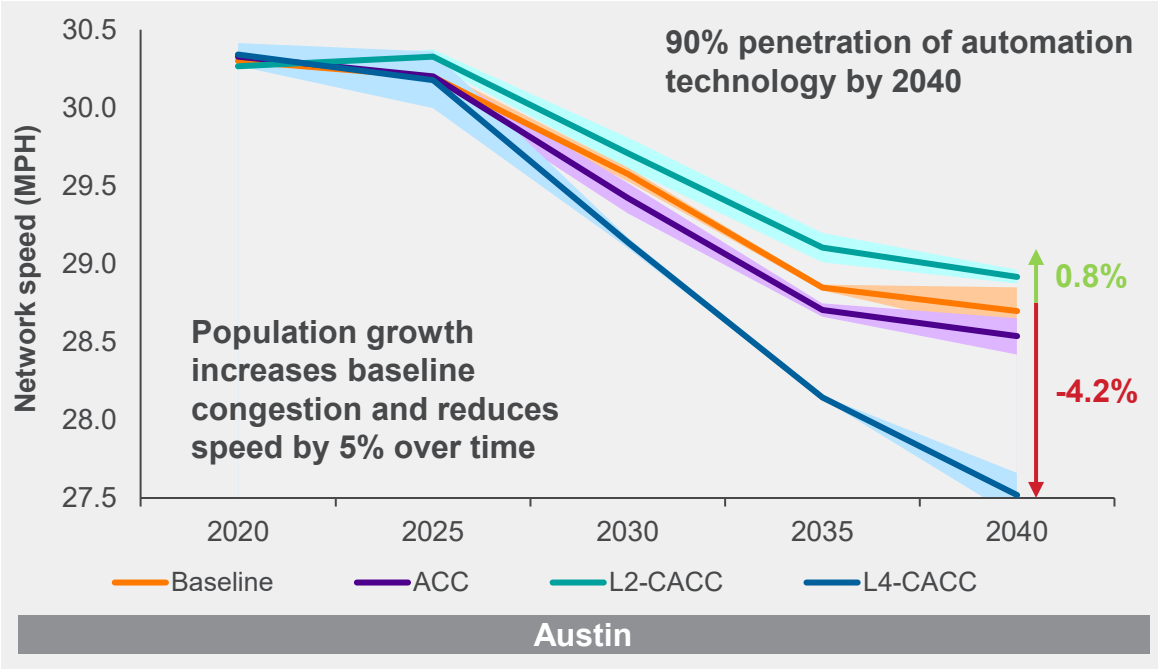
CACC: Cooperative Adaptive Cruise Control

CACC CAN IMPROVE MOBILITY AT LOW LEVELS OF AUTOMATION

But highly automated highway driving increases miles traveled by 7%

- Impacts over time show evolution of land use, mobility under:
  - Adaptative cruise control (ACC)
  - Cooperative adaptive cruise control (CACC)
  - CACC level 4 automation (L4)
- L2 increases network performance but L4 reduces speeds by 5% due to increased travel from lower time cost

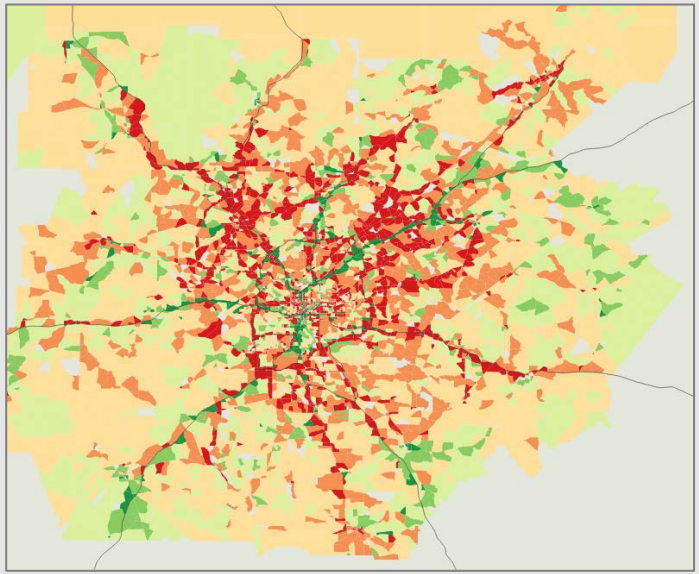
- Planners should account for higher congestion and slower travel speeds in a future with highly automated highway driving



LEVEL 4 AUTOMATED DRIVING MAY INCREASE GREENHOUSE GAS EMISSIONS

- Level 4 automated highway driving encourages longer highway travel, so emissions increase
- Most of the impact is concentrated around highways leading to potential equity issues

- Mitigation strategies should focus on highways and outlying areas where emissions tend to increase

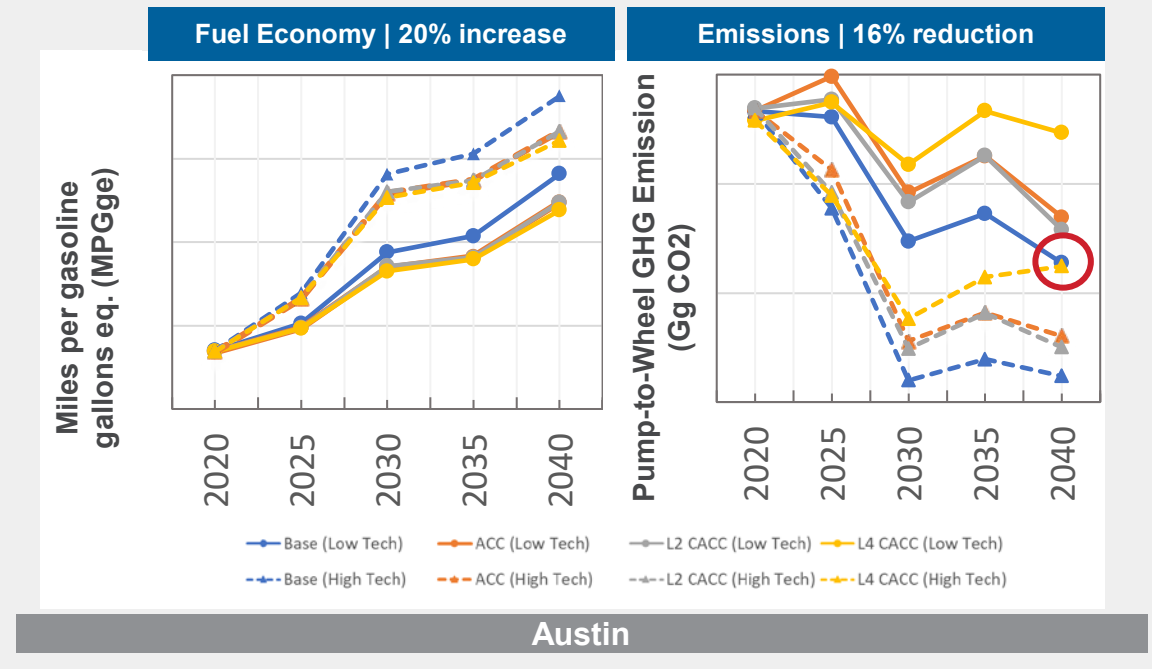


ADVANCED POWERTRAIN TECH TARGETS IMPROVE MPG, REDUCE EMISSIONS BY 2040

Counteracts impact of accessory load and VMT from automation

- Impact assessed under real-world driving conditions using transportation system simulations for a 20-year period
- Advanced mobility has a modest impact on improving consumption compared to technology targets
- All powertrain R&D advances needed to maintain emissions levels achievable at baseline technologies without automation

- Collaboration between the government and industry can play a crucial role in decarbonizing travel

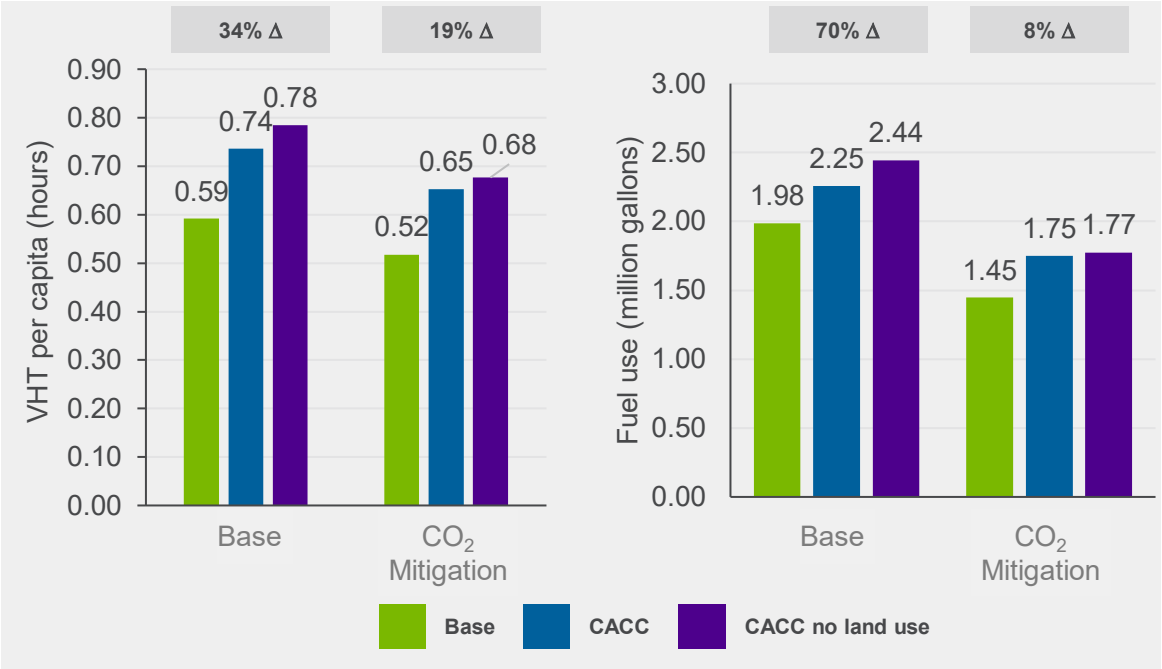


IGNORING LAND USE CHANGE BIASES FINDINGS

VHT and fuel impact is 8–70% higher in 2040 when ignoring land use change

- Comparing results with and without land use
- Shows that land use adapts to mobility changes driven by VOT decrease over time
- Carbon mitigation policy is effective at reducing CACC impacts

- Need to consider land use and household decision-making when evaluating technologies and policies



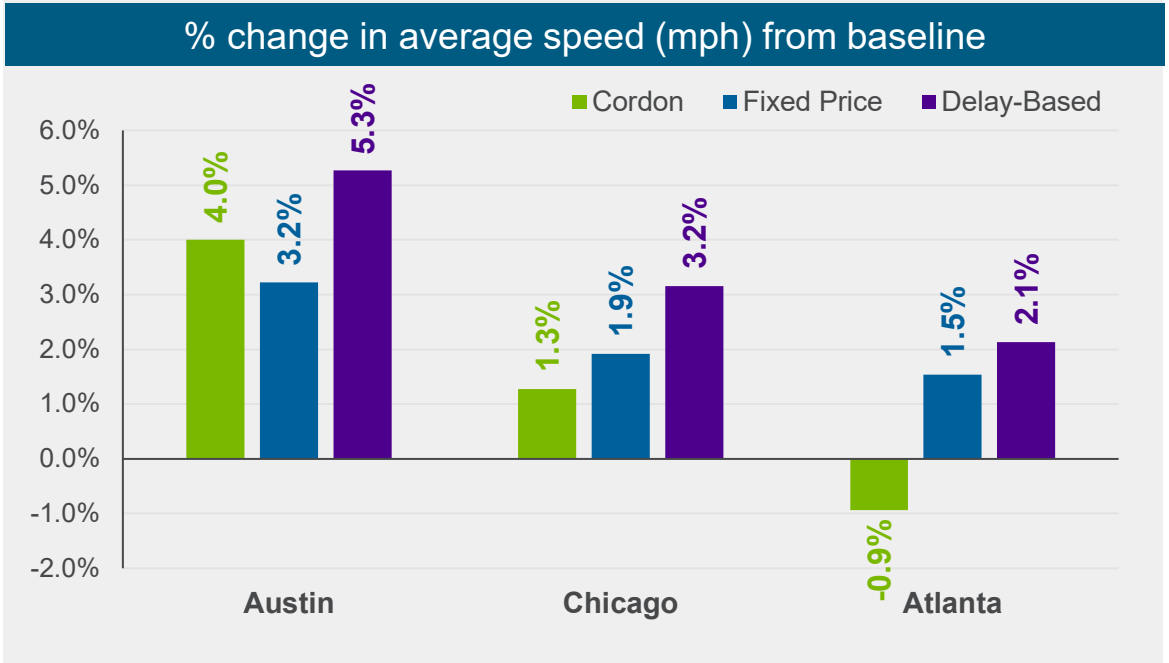
VHT: vehicle hours traveled

CONGESTION PRICING PROVIDED BENEFITS IN THREE METROPOLITAN AREAS

Delay-based congestion pricing is most effective method

- "Fair" comparison of different pricing strategies set to collect similar revenue
- Almost all strategies improve speed to varying degrees
- Cordon gets higher revenue in the peak but causes more deflection
- Average price per trip less than $0.50, but significant benefits are observed

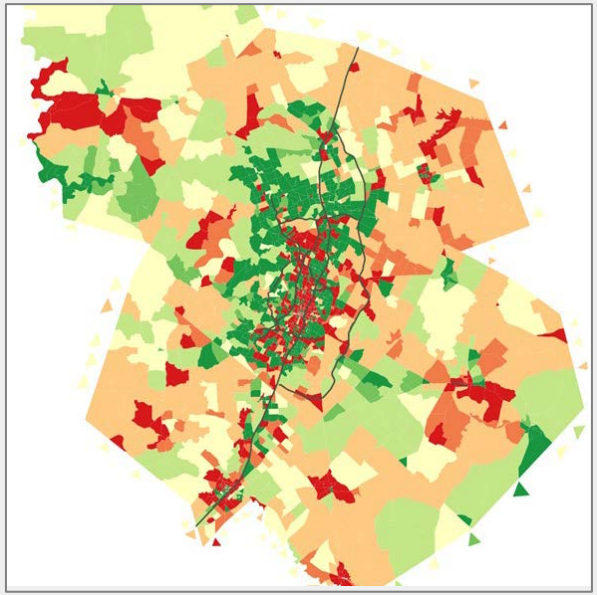
- Charging a delay-based road price is most effective at reducing congestion, increasing speeds up to 5%



CARBON PRICING CAN HELP MITIGATE LAND USE IMPACT OF LEVEL 4 AUTOMATED DRIVING

- Applied increased costs for carbon emissions over time coupled with electric vehicle subsidies
- Reduces additional driving hours due to CACC by 12%
- Carbon pricing reduces emissions from Level 4 automated driving by up to 25% when considering land use change

- Well-designed policies can prevent the increased travel miles and other impacts from highly automated driving



Δ Level 4 Ref 2040 vs. Base Ref 2020

Δ Population density per/km²

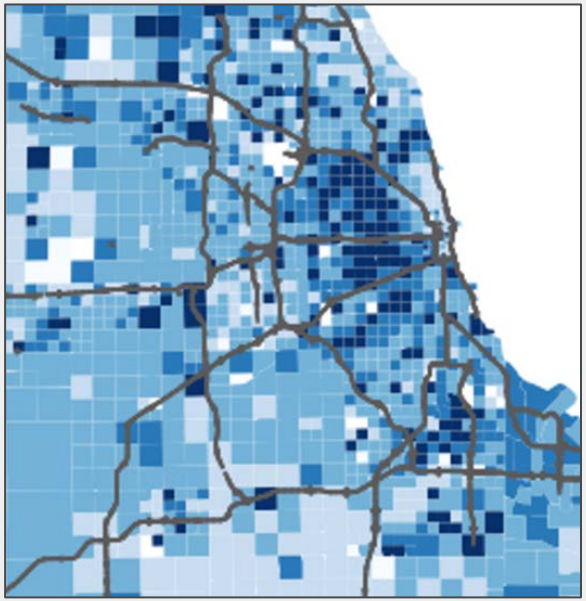
	< - 50
	-50 – -25
	-25 – -2
	-2 – 2
	2 – 25
	25 – 50
	> 50

Austin

ROAD PRICING COST INCREASES HIGHEST IN LOW-INCOME AND EXURBAN AREAS

- Delay based congestion pricing can increase network speed up to 11%
- Costs are not borne uniformly across the region
- Total travel cost increases can reduce daily income by up to 7.5%

- Agencies should explore ways to reinvest revenue from congestion pricing to reduce travel cost burden



Δ Daily Income (%)

> 0%
0.0% to -2.5%
-2.5% to -5.0%
-5.0% to -7.5%
< -7.5%

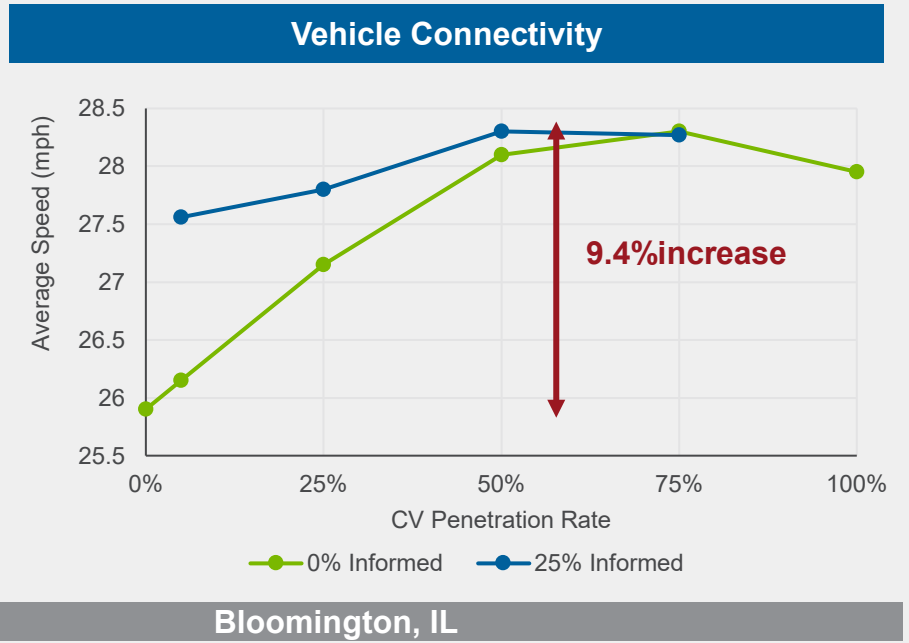
Chicago Metro

CONNECTIVITY-ENABLED CONTROL IMPROVES TRAFFIC SPEED UP TO 10%

Information exchange provides benefits regardless of automation level

- Best cases of 50% to 75% connected vehicle penetration rate yield speed improvement around 10%
- Covering 15% of links with roadside units is sufficient to detect 80% of traffic — little benefit in speed improvement beyond this level

- Better coordination schemes (i.e. optimized routing) can further improve performance

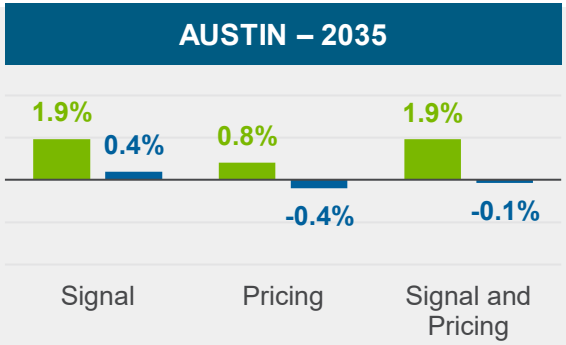


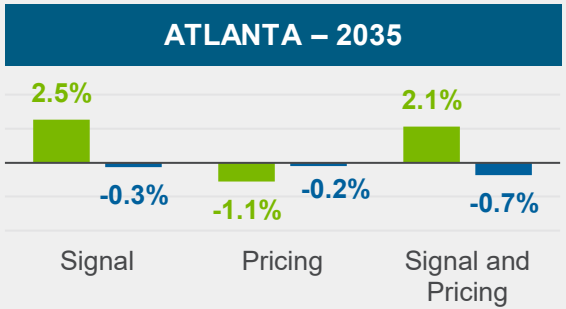
INVESTMENT IN TRANSPORTATION NETWORKS CAN IMPROVE MOBILITY

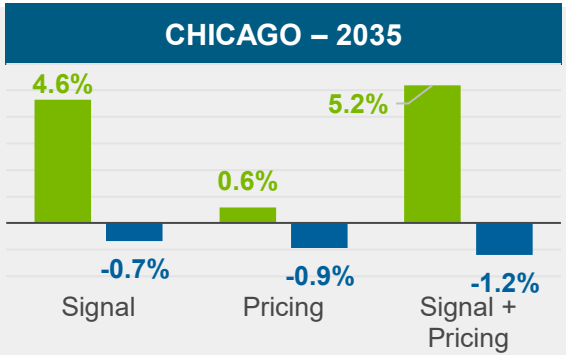
Connected signals are especially impactful in Chicago

- Signal timing led to speed improvements of around 2-5% in three cities
- Cordon pricing had smaller and mixed impacts — less on speed, more on VMT

- Adaptive signal timing strategy leveraging vehicle connectivity has potential to replace costly infrastructure and improve signal performance







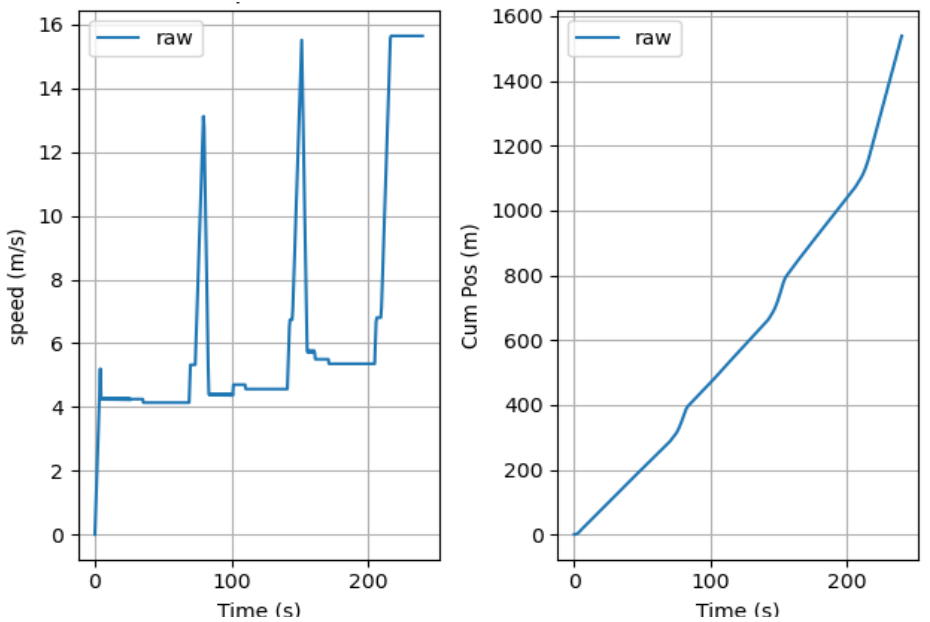
ECO APPROACH AND DEPARTURE (EAD) CAN REDUCE ENERGY CONSUMPTION BY 22%

Preliminary results for four intersections in Detroit

- Slight speed improvement (probably due to dynamic traffic assignment)
- 22% decrease in energy consumption on the corridor
- Consistent with microsimulation estimates of potential gains

- Research suggests that EAD can help to save energy with minimal impact on other mobility indicators

Detroit - Corktown



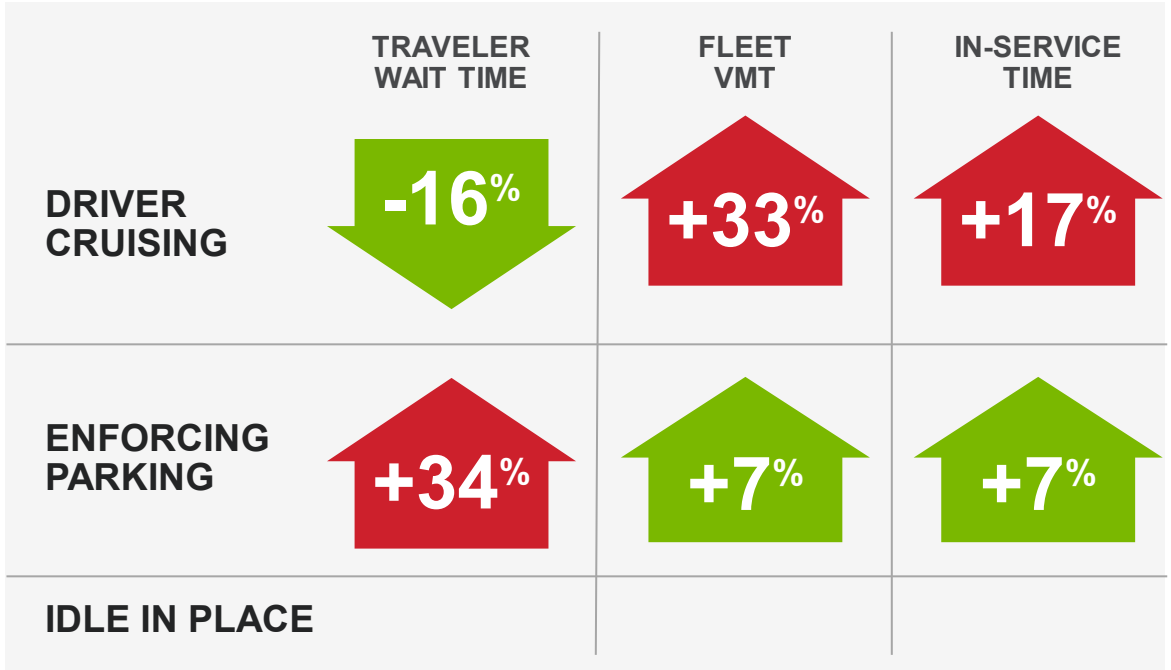
Metric	No EAD	With EAD
Total Travel Time (h)	2909	2854
Average Speed (mph)	14.7	15.0
Energy Use (j/m)	675	523

PARKING BETWEEN RIDEHAILING TRIPS COULD DECREASE EMPTY VMT BY 25%

Compared to driver cruising

- Driver cruising lowers traveler wait time at the expense of increased VMT and in-service time
- Driving to parking between trips would decrease empty VMT by 25% in urban dense areas with 18% increase in traveler wait time

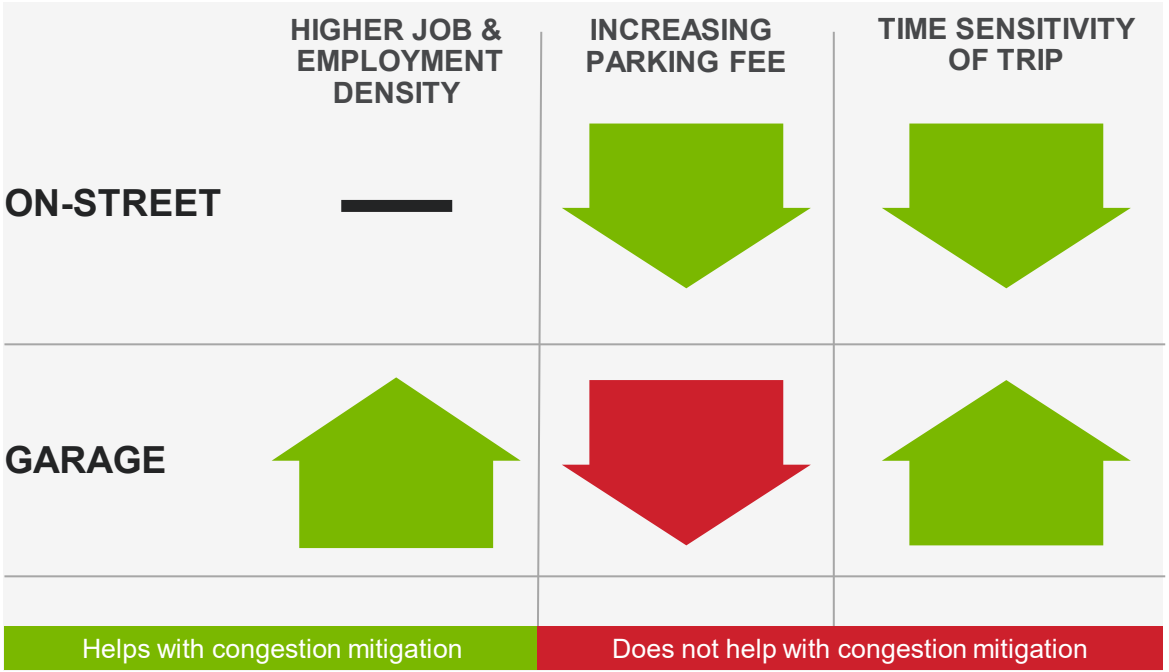
- Cities could start tracking parking and improve use of limited resource through curb management



INFLUENCING PARKING DECISIONS CAN HELP LOWER NETWORK CONGESTION

- Job density & pop. density implies greater chance to use garages as expected
- Parking fee plays important role in differentiating on-street and garage decisions
- Timeliness necessitates reliable garage parking rather than cruising for on-street parking

- Dynamic pricing and allocation of available parking slots by cities is crucial in managing demand

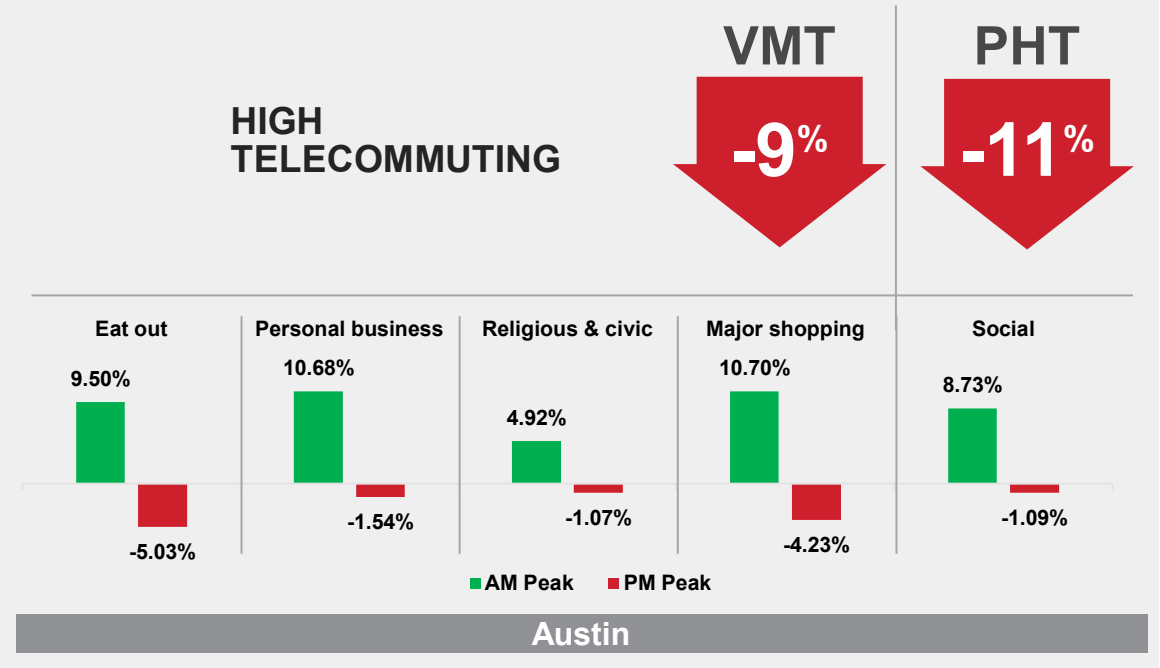


HIGH TELECOMMUTING REDUCES OVERALL VEHICLE MILES TRAVELED

Passenger hour travel (PHT) could be reduced by 11%

- Flexible work schedules could reduce peak-period commuter trips by 20%
- High telecommuting could reduce out-of-home travel by 6%, decreasing VMT and PHT by 9% and 11%, respectively
- Non-work activities increase in the morning peak period and decrease during evening peak period — enabled by high telecommuting

- Policymakers could apply telecommuting incentives to reduce network congestion



HIGH TELECOMMUTING LEADS TO SUBSTANTIAL REDUCTION IN EMISSIONS

Fine particulate matter (PM2.5) emissions lowered by 6.6% in Atlanta

- High telecommuting reduces overall travel hours by 11% reducing emissions by 7%
- Highest reductions concentrated downtown and along radial highways
- Some increases in outlying areas and highways connecting suburbs

- Telecommuting incentives can reduce air pollution, especially in downtown areas

TECHNOLOGY AND DEMAND IMPACTS UNIQUE TO EACH METROPOLITAN AREA

Scenario impact on total travel hours in Austin, Atlanta and Chicago

- Signal coordination highly impactful in Chicago, less so in Austin and Atlanta
- Cordon pricing not effective except in Austin
- Teleworking reduces VHT from 11% to 16%, with higher potential in Chicago, but negates some benefits of signal and transit investment

- Agencies should not assume existing deployed policies will have similar impacts in different locations

% Change in regional travel time given investment in:	Austin	Atlanta	Chicago
Cordon	-0.9%	0.0%	0.1%
Signal coordination	-2.6%	-3.6%	-5.3%
FMLM	0.3%	-0.1%	-0.8%
Transit	0.5%	-0.1%	-1.2%
For different demand scenarios:			
High CACC/EV	0.2%	-0.9%	0.2%
High Teleworking	-11.2%	-11.6%	-16.3%
And interactions between supply and demand:			
Telework + Signal	0.6%	0.6%	1.7%
Telework + Transit	0.4%	0.4%	0.4%
Pricing + FMLM	0.0%	0.5%	-0.2%
Pricing + Transit	-0.7%	0.0%	0.0%
Signal + Transit	0.0%	0.0%	-0.4%

AUSTIN, ATLANTA AND CHICAGO HAVE DIFFERENT ENERGY REDUCTION POTENTIAL

Vehicle technologies reduce energy up to 30%; mobility up to 9%

- Signal coordination and teleworking have similar impact ~1% and ~6% reductions, respectively
- Advanced vehicles reduce energy more in Austin, but average ~-26%
- Transit has an energy benefit in Chicago, but not observable in Austin, mostly due to low mode share

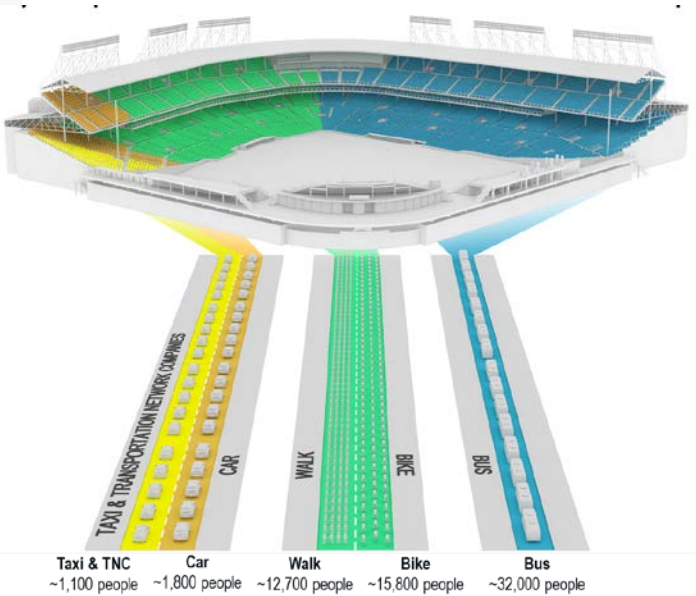
- Stakeholders should consider how different interaction effects observed in each city partially offset energy benefits

% Change in regional energy consumption			
	Austin	Chicago	Atlanta
CACC/EV	-29.7%	-24.3%	-26.1%
Teleworking /e-comm	-5.6%	-6.0%	-7.1%
Signal coordination	-1.5%	-0.9%	-0.2%
Signal + CACC/EV	1.4%	0.5%	0.3%
Cordon + Telework	0.0%	0.0%	-1.9%

RELEVANCE OF CURB MANAGEMENT AND CURB METRICS

- Prioritize performance metrics to reach context-specific goals. Weight – and understand correlations – between energy efficiency, economics, safety, emissions, and equity.
- Performance metrics that focus on people and goods access (not just vehicles).
- Prioritization of performance metrics is key to optimize curb management and set curb allocation.
- There exists a huge gap of data inventories (and data collection) to calculate performance metrics.

Quantity of People Who Can Travel Per Hour Per Lane Via Various Modes of Transportation



CURB USE IS A SIGNIFICANT LOCAL POLICY ISSUE IN TRANSPORTATION ENGINEERING

- Municipalities are grappling with curb use as an engineering problem
- Curb congestion impacts travel speed vs vehicle flow (i.e., fundamental diagrams), greenhouse gas emissions, system energy efficiency and productivity
- Microscopic simulation gives cities affordable mechanisms to explore alternative curb allocations

- Municipalities should factor curb use into planning since it is critical for optimizing energy supply chains, including curbside charging for electric vehicles

I-5 looking south toward Seattle[1]

The Seattle-Tacoma Airport departures curb drop off[2]

1. Image Credit: SounderBruce CC 2, via Wikimedia Commons
2. Image Credit: Port of Seattle, CC 0

LOADING ZONES CAN BOOST THE EFFICIENCY OF RELEVANT CURB USE

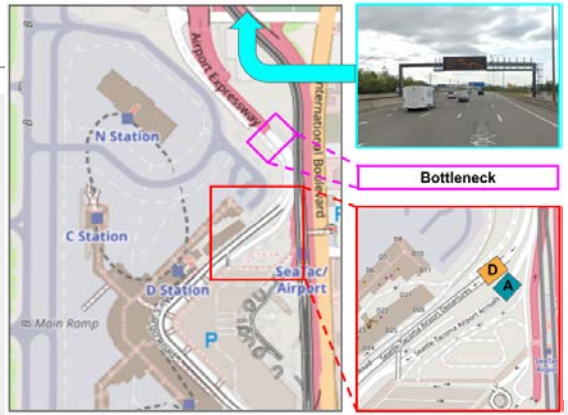
- **Metrics measured include: (a) Curb productivity in terms of passengers and goods (b) Curb accessibility (C) Emissions**
- **PLZs improve curb productivity in terms of number of passengers served by 6%**
- **Goods productivity (24-64%) and commercial vehicle accessibility (21-40%) improved by adding CVLZs**
- **No statistically significant difference in emissions, suggesting curb allocation is not the best way to achieve this goal**
- **Practitioners can most effectively maximize access and productivity by placing PLZs and CVLZs on different but adjacent/nearby streets**

Maxner, et. al., "Simulation-based Analysis of Different Curb Space Type Allocations on Curb Performance", Transportmetrica B: Transport Dynamics Volume 11, 2023 - Issue 1

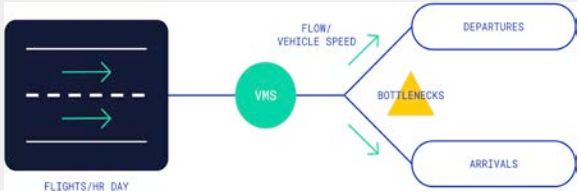
VARIABLE MESSAGE SIGNS CAN REDUCE TRAFFIC CONGESTION

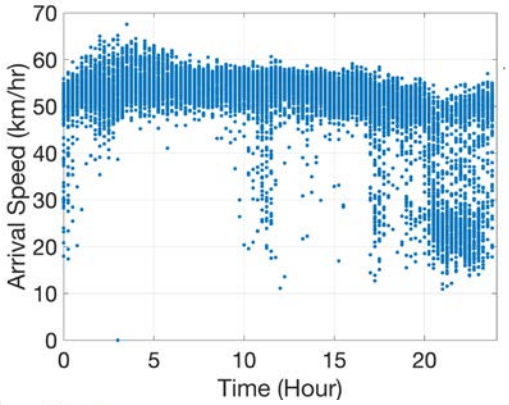
- We collected speed-flow data at arrival and departure terminals of SeaTac to study traffic congestion
- Our analysis shows different congestion times for arrival and departure terminals
- This difference is shown to depend on the volume of arrival and departure of flights per hour
- Variable message signs (VMS) have the potential to reduce traffic congestion through diversions

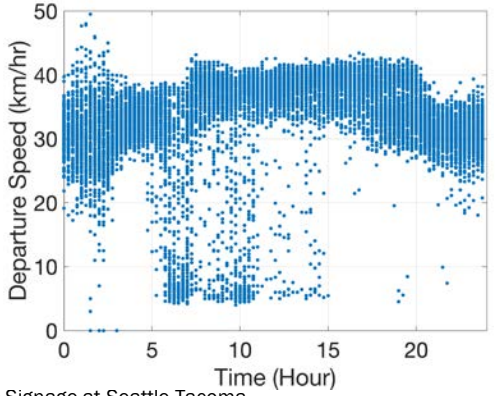
- Airports can use non-infrastructure-based methods like VMS to manage traffic congestion and reduce emissions by a total of 90 to 360 kilograms of CO_2 per hour.



The physical layout of the VMS, traffic bottleneck, and arrival and departure drives and the locations of respective speed and flow sensors labeled A and D





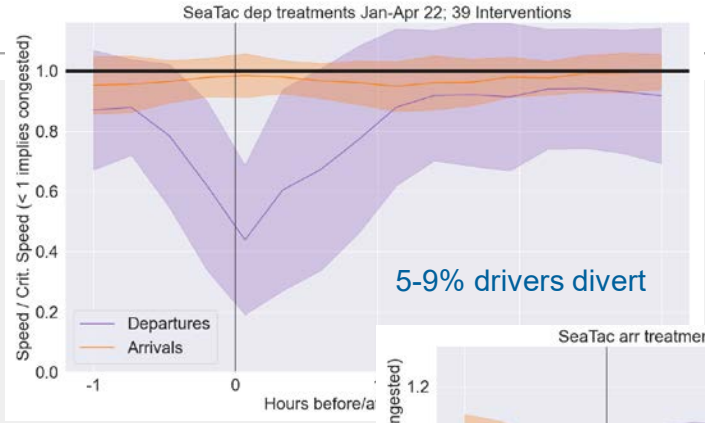


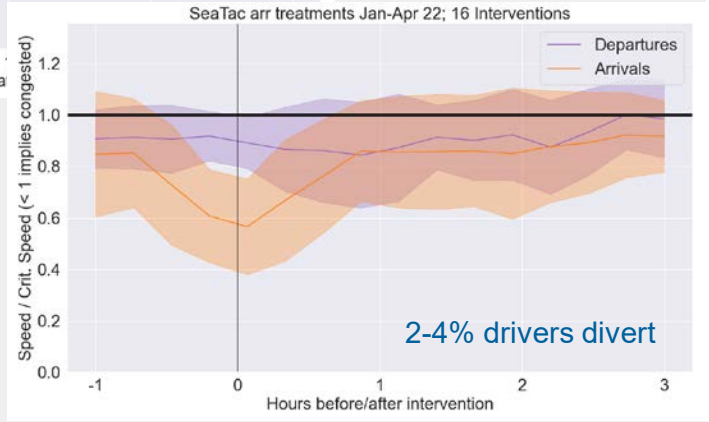
Vasisht, et. al., Transport Findings, September 2022, "Estimating Driver Response Rates to Variable Message Signage at Seattle-Tacoma International Airport"

VARIABLE MESSAGE SIGN COMMUNICATION INFLUENCES DRIVER RESPONSE

- We studied the effectiveness of VMS in reducing congestion based on historical speed-flow data and VMS data from SeaTac
- We analyzed how speeds change (up to 300%) before/after the diversions were applied
- The response rates to VMS at SeaTac were different at arrival and departure terminals
- 5-9% of drivers divert from departures to arrivals
- 2-4% of drivers divert from arrivals to departures
- The difference in response rates can be explained based on convenience to drivers

- Airports should consider the difference in diversionary response rates when setting up VMS control policy and monitor the effectiveness of different forms of communications with drivers



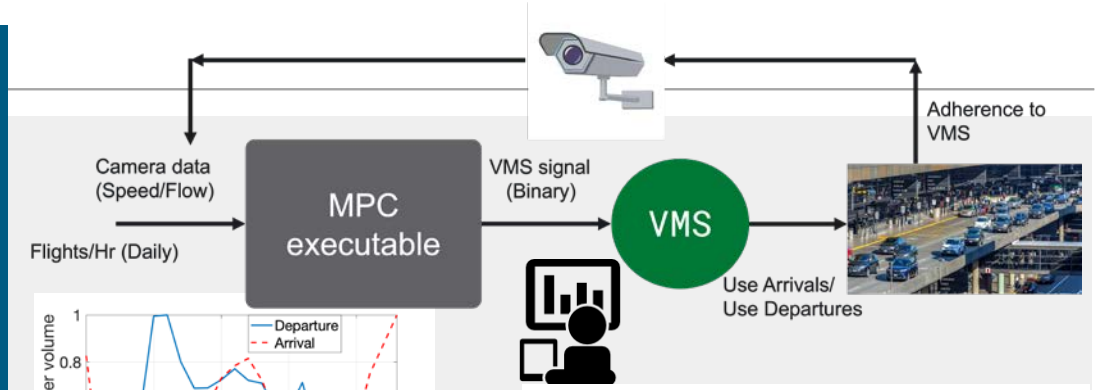


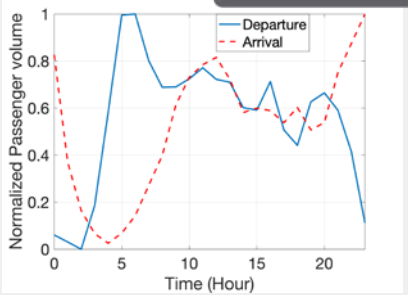
Vasisht et al. *"Estimating driver response rates to variable message signage at Seattle-Tacoma International airport"*, Transport findings 2022

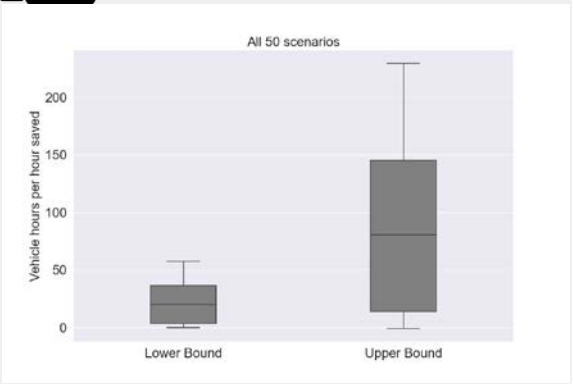
AUTOMATING VARIABLE MESSAGE SIGNS CAN INCREASE TRAVEL SPEEDS

- Model Predictive Control (MPC) based automation of VMS at airports can further reduce traffic congestion
- Our simulations suggest that automated interventions could have increased travel speeds up to 300% during untreated congested periods
- This could have saved between 30 to 80 vehicle hours per hour for drivers leading to improvements in efficiency and emissions

- Airports can attain significant improvements in traffic congestion and emissions through predictive and automated control of VMS







SUMMARY OF KEY INSIGHTS

Connectivity and automation can improve mobility, but fully automated driving increases congestion, energy and emissions

Pricing strategies can be used to limit impact of automated driving, with delay-based pricing most effective

Vehicle-to-X connectivity can improve mobility and energy through better signal coordination, better routing and better trajectory planning

Vehicle technology improvements account for 70% of energy reduction, but mobility and operations are 30%

Curb access and productivity can be maximized by placing passenger loading zones and commercial vehicle loading zones on different but adjacent streets

Airports can attain significant improvements in traffic congestion through automation of VMS saving 30-80 vehicle hours per hour and 90-360 Kg of CO_2 per hour

CHICAGO METRO

PREVIOUS & UPCOMING WEBINARS

FEBRUARY
OVERVIEW, KEY METRICS AND INSIGHTS SNEAK PEEK

MARCH
MULTIMODAL TRAVEL
Transit & Ridehail

APRIL
MULTIMODAL TRAVEL
Micromobility
Drones

MAY
CONNECTED & AUTOMATED VEHICLES (CAVs)
Vehicle and powertrain control
Traffic signal control

JUNE
CAVs and Intelligent Transportation Systems
Transportation system impact, induced VMT, parking, curb management, land use, policies

Up Next

JULY
FREIGHT
Last mile delivery

AUGUST
ELECTRIFICATION
EV charger deployment
Grid impact

2023

Webinar Materials

U.S. DEPARTMENT OF ENERGY

SMARTMOBILITY

Systems and Modeling for Accelerated Research in Transportation

General questions, comments, please contact
eems@ee.doe.gov

U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Argonne NATIONAL LABORATORY

BERKELEY LAB

INL Idaho National Laboratory

NREL NATIONAL RENEWABLE ENERGY LABORATORY

OAK RIDGE National Laboratory

Pacific Northwest NATIONAL LABORATORY